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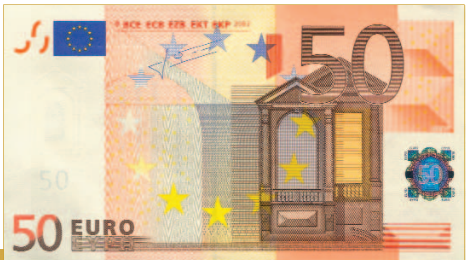

In 2005 all ECB publications will feature a motif taken from the €50 banknote.

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CONTENTS

Abstract

We investigate the role of economic transparency within the framework of one of Townsend's models of 'forecasting the forecasts of others'. The equilibrium has the property that 'higher order beliefs' are coordinated into a finite-dimensional setup that is amenable to address monetary policy issues. We focus here on the role of public information about the money supply, and find that it should be fully revealing.

JEL Classification: D82, E58

Keywords: Transparency, central banks, asymmetric information, public information

Non-Technical Summary

Central bank transparency has been a key issue under discussion with the move toward greater central bank independence. The most strikingly simple example of how too much transparency can be costly is if a central bank is willing to release all its information about a supply shock. It is then unable optimally to affect employment, because the unexpected component of inflation is zero, so there can be no trade-off of the effects of the shock between inflation and unemployment. Only if it restricts this information, can it react in a manner that is beneficial to society.

Debate on transparency has been fostered by the accompanying requirement of greater accountability in order to justify greater independence. Thus the evaluation of the performance of central banks can only be achieved by an improvement in accountability. This takes the general form of an increase in communication with the public, coupled with the acceptance of repercussions from any disasters, such as the dismissal of bank officials. Such accountability is associated with the notion of transparency, of which there are five aspects: political, economic, procedural, policy and operational. This paper is concerned directly with just one of these, namely economic transparency, and focuses on the information that is used for monetary policy.

Since "accountability directly affects the central bank's incentives, whereas incentive effects of transparency only operate indirectly through private sector expectations", it follows that some form of transparency is essential. With central banks only controlling the overnight rate, there needs to be some other mechanism by which monetary policy can coordinate expectations. The motivation for central banks not being fully transparent is then twofold. Firstly, there is the potential for market participants to be unduly influenced by a central bank judgement that may be misguided. This is hardly a new insight, and central banks have in the past developed their own coping mechanisms for announcements and dealings with the press. Secondly, there is a trade-off between early publication of data and the discovery of subsequent error, and the consequent loss of reputation due to the latter is likely to be the main factor in deciding not to be fully transparent.

A number of recent papers have moved away from the more conventional approach to economic transparency, which involves a single representative private agent. The standard literature comes up with results about whether social welfare is enhanced or not as a consequence of having greater information, and is addressed analytically by the choice of an optimal level of the noise to signal ratio. The more recent literature addresses the same questions within a framework where there are private agents with diverse information sets, and is largely based on the island model of Lucas, but with imperfectly competitive markets. In this model individual pricing decisions are made on the basis of private information on the money supply and expectations of the current aggregate price index, which is a weighted sum of all current pricing decisions. For the most basic model that it may not be optimal (in welfare terms) for public information to be fully revealing.

One of the major problems with the above model are the informational assumptions, notably that the consumer price index is not known, but must be inferred. It is essential therefore to investigate the case of heterogeneous agents within a more realistic informational framework. Fortunately, in some recent work, a particular example of the 'forecasting the forecasts of others' problem has been solved. Underlying this is an intertemporal profit maximization problem for firms, in which all prices are observed but only one's own current output can be measured. There is a common demand shock, here interpreted as due to the money supply following a stochastic process, coupled with idiosyncratic demand shocks as well. In this paper we add an additional noisy public information signal about the current value of the money supply. Thus agents must disentangle their own information from inferences about other agents' information. Once the solution has been described, we are able to obtain a value for the expected welfare gain for firms. Of course this is insufficient for calculating a measure of social welfare, so we add this to our discussion, and couple it with the assumption that the variance of prices is important as well.

All the welfare effects, whether associated with firms, consumers or price stability, lead to the conclusion that public information should be fully revealing with regard to aggregate demand (money supply) shocks.

1 Introduction

Central bank transparency has been a key issue under discussion with the move toward greater central bank independence. Cukierman (2001) and Geraats (2002) have summarised the main theoretical points using a simple Barro-Gordon framework, with varying informational assumptions. The most strikingly simple example of how too much transparency can be costly is afforded by Cukierman (2001), who shows that when a central bank is willing to release all its information about a shock, it is unable optimally to affect employment, because the unexpected component of inflation is zero. Only if it restricts this information, can it react in a manner that is beneficial to society.

Debate on transparency has been fostered by the accompanying requirement of greater accountability in order to justify greater independence. Thus the evaluation of the performance of central banks can only be achieved by an improvement in accountability. This takes the general form of an increase in communication with the public, coupled with the acceptance of repercussions from any disasters, such as the dismissal of bank officials. Such accountability, while associated with, does not of course come under, the aegis of transparency for which Geraats (2002) distinguishes five aspects: political, economic, procedural, policy and operational. This paper is concerned directly with just one of these, namely economic transparency, and focuses on the information that is used for monetary policy. Svensson and Woodford (2003) is a good example of political transparency, with its emphasis on inflation targeting, with Walsh (2001) covering contracts and Schaling and Nolan (2001) addressing (a somewhat primitive form of) preference uncertainty. Operational transparency has been discussed by Faust and Svensson (2001), and involves the degree to which the imperfectness of control (i.e. the control error) over inflation is revealed. Their additional focus on the indirect observability of central bank's preferences and objectives has its roots in Cukierman and Meltzer (1986). Procedural transparency centres around individual voting records, and minutes of monetary policy committee meetings. Policy transparency is the disclosure of policy decisions and of likely future policy; testing for market effects of associated policy statements is in its infancy.

Geraats (2002) makes the point that "accountability directly affects the central bank's incentives, whereas incentive effects of transparency only operate indirectly through private sector expectations". Some form of transparency is therefore essential, for as Blinder (1998) argues, with central banks only controlling the overnight rate, there needs to be some other mechanism by which monetary policy can coordinate expectations. The motivation for central banks not being fully transparent is then twofold. Firstly, there is the potential for market participants to be unduly influenced by a central bank judgement that may (hopefully no more than occasionally) be misguided (Amato *et al.* (2003)). This is hardly a new insight, and central banks have in the past developed their own coping mechanisms for announcements and dealings with the press. Secondly, there is a trade-off between early publication of data and the discovery of subsequent error, and the consequent loss of reputation due to the latter is likely to be the main factor in deciding not to be fully transparent.

A number of recent papers have moved away from the more conventional approach to economic transparency, which involves a single representative private agent. The standard literature comes up with results about whether social welfare is enhanced or not as a consequence of having greater information, and is addressed analytically by the choice of an optimal level of the noise to signal ratio. The more recent literature addresses the same questions within a framework where there are private agents with diverse information sets, and is largely based on the island model of Lucas, but with imperfectly competitive markets. Woodford (2001) is the pioneer of this new literature, although his initial work was intended to produce long drawn out business cycle effects. The idea behind his model is that individual pricing decisions are made on the basis of private information on the money supply (where the quantity theory of money with constant velocity always applies) and expectations of the current aggregate price index. The latter is a weighted sum of all current pricing decisions, which leads to an infinite set of iterated expectations, all dependent on the underlying stochastic process for the money supply; Woodford (2001) neatly shows that the reduced form solution can be expressed in finite form. Amato *et al.* (2003), Hellwig (2002) and Morris and Shin (2002) use this model as a workhorse to investigate the effects of an additional source of public information, and find for the most basic model that it may not be optimal (in welfare terms) for public information to be fully revealing. In addition, Hellwig (2002) also examines this model in an optimal policy context, but finds that public announcements should always be fully revealing.

One of the major problems however with the model are the informational assumptions. As Svensson (2001) points out, it would be an unusual private agent who would not have good information on the consumer price index, so it is essential to investigate the case of heterogeneous agents within a more realistic informational framework. Fortunately, in some recent work, Pearlman and Sargent (2003) have solved a particular example of the 'forecasting the forecasts of others' problem posed by Townsend (1983). Underlying this is an intertemporal profit maximization problem for firms, in which all prices are observed but only one's own current output can be measured. There is a common demand shock, here interpreted as due to the money supply following a stochastic process, coupled with idiosyncratic demand shocks as well. In this paper we add an additional noisy public information signal about the current value of the money supply. Thus agents must disentangle their own information from inferences about other agents' information. Once the solution has been described, we are able to obtain a value for the expected welfare gain for firms. Of course this is insufficient for calculating a measure of social welfare, so we add this to our discussion, and couple it with the assumption that the variance of prices is important as well.

Section 2 describes the intertemporal model, and outlines the solution method, while drawing on the exact solution from Pearlman and Sargent (2003). Section 3 discusses the welfare gains and losses, and highlights the crucial issues for public information in this setup. Section 4 compares our results with those from analyses with a single representative agent based on the Barro-Gordon model, and those in the more recent work cited above. Section 5 concludes.

2 The model

This section describes Townsend's basic model of an industry, then solves it under certain assumptions about what decision makers observe. Firms in each of two industries $i = 1, 2$ employ a single factor of production capital, k_t^i, to produce output of a single good, y_t^i. We let capital letters denote market wide objects and lower case letters denote objects chosen by a representative firm. A representative firm in industry i has production function $y_t^i = fk_t^i$, where henceforth we normalize so that $f = 1$; it acts as a price taker with respect to output price P_t^i, and maximizes

$$E_0^i \sum_{t=0}^{\infty} \beta^t \left\{ P_t^i f k_t^i - .5h(k_{t+1}^i - k_t^i)^2 \right\}, \quad h > 0. \tag{1}$$

Demand in industry i obeys

$$P_t^i = -bY_t^i + \theta_t + \epsilon_t^i, \quad b > 0, \tag{2}$$

where $Y_t^i = K_t^i$ is total output in market i, θ_t is the persistent component of a demand shock that is common across the two industries and which we shall interpret as a money supply shock, and ϵ_t^i is an industry specific component of the demand shock that is i.i.d. with variance σ_ϵ^2. We assume that θ_t satisfies

$$\theta_{t+1} = \rho\theta_t + v_{t+1} \tag{3}$$

where $\{v_{t+1}\}$ is an i.i.d. sequence of Gaussian shocks with mean zero and variance σ_v^2. Following on from Blinder (1998) and, for example Gerlach (2003), who suggests that the ECB's two pillars have the consequence that the link between M3 growth and interest rates is not strong, it is reasonable to assume that $\sigma_v^2 > 0$. To simplify notation, we set $h = 1$. In equilibrium, $k_t^i = K_t^i$, but as usual we must distinguish between k_t^i and K_t^i when we pose the firm's optimization problem.

The first term in (1) is revenue, while the second term represents adjustment costs. Since we focus on deviations from equilibrium, we have omitted a (constant) cost of capital term, as it merely introduces a constant term into the solution.

Townsend (1983) assumed that at time t firms in industry i observe k_t^i, Y_t^i, P_t^i, $(P^{-i})^t$, where $(P^{-i})^t$ is the history of prices in the other market up to and including time t.

Notice that because the representative firm i sees the aggregate state variable Y_t^i in its own industry, as well as the price, it can infer the total demand shock $\theta_t + \epsilon_t^i$. However, at time t, the firm sees only P_t^{-i} and does not see Y_t^{-i}, so that firm i does not appear to see $\theta_t + \epsilon_t^{-i}$

In addition we assume that there is a further noisy public signal on monetary aggregates provided by the central bank $\theta_t + w_t$, where $\{w_t\}$ is an i.i.d. sequence of Gaussian shocks with mean zero and variance σ_w^2. This can be regarded as a signal which is a summary of press statements, publications and announcements by bank officials.

A remarkable result due to Kasa (2000) is that in the end, the firm in industry i will be able to infer the composite shock $\theta_t + \epsilon_t^{-i}$ from the data that it does observe at t. In a later development, Pearlman and Sargent (2003) showed how fully to characterize the solution. We shall not repeat the steps in the solution procedure, but will briefly work through the logic after presenting the full solution.

Firstly, standard first-order conditions for (1) yield a relationship between k_t^i, its lagged value and anticipated future values of itself and of θ_t and ε_t^i. Secondly, assume that all information is pooled; using the partial information results of Pearlman *et al.* (1986) one obtains the following solution:

Proposition 1

$$k_{t+1}^i = \frac{1}{\beta\lambda}k_t^i - \frac{p}{1+p(\frac{2}{\sigma_\varepsilon^2}+\frac{1}{\sigma_w^2})}\frac{\rho}{\rho-\lambda}[\frac{1}{\sigma_\varepsilon^2}(\varepsilon_t^1+\varepsilon_t^2)+\frac{1}{\sigma_w^2}w_t] - \frac{\rho}{\rho-\lambda}\theta_t + \frac{1}{1+p(\frac{2}{\sigma_\varepsilon^2}+\frac{1}{\sigma_w^2})}\frac{\rho}{\rho-\lambda}\widetilde{\theta}_t \tag{4}$$

where

$$\widetilde{\theta}_{t+1} = \frac{\rho}{1+p(\frac{2}{\sigma_\varepsilon^2}+\frac{1}{\sigma_w^2})}\widetilde{\theta}_t - \frac{p\rho}{1+p(\frac{2}{\sigma_\varepsilon^2}+\frac{1}{\sigma_w^2})}[\frac{1}{\sigma_\varepsilon^2}(\varepsilon_t^1+\varepsilon_t^2)+\frac{1}{\sigma_w^2}w_t] + v_t, \tag{5}$$

the Riccati equation for the innovations process for θ_t, $\widetilde{\theta}_t = \theta_t - E_{t-1}\theta_t$ satisfies

$$p = \frac{\rho^2 p}{1+p(\frac{2}{\sigma_\varepsilon^2}+\frac{1}{\sigma_w^2})} + \sigma_v^2 \tag{6}$$

and λ is the larger root of the

$$(\lambda-1)(\lambda-1/\beta) = b\lambda, \tag{7}$$

and corresponds to the eigenvalue associated with the saddlepath of the optimal solution.

Proof See Appendix for an outline of this.

Note that the smaller root is then given by $1/\beta\lambda$, and it is straightforward to show that this is less than 1. The equations above are slightly different from those in Pearlman and Sargent (2003) because of the inclusion of the extra term w_t from the public signal for money supply.

The final logical step is to assume that the solution above is correct for industry 1, and then to work through the partial information solution for industry 2, assuming that the information available is both sets of prices, the public signal, and industry 2's capital stock. When this is done, one obtains an identical process for k_t^2 to that in (4), and the same representation of the innovations process. Once again, we note that the algebra is slightly more tedious than in Pearlman and Sargent (2003) because of the presence of the public signal. The bottom line therefore is that the solution with pooled information is identical to that where the information sets are diverse and unpooled; incorporating one another's expectations does not in this case lead to an infinite regress as Townsend expected, but to a much simpler inference problem in equilibrium.

Before closing this section, we summarize the covariance properties of the system, which are obtained using standard methods:

$$var(\theta) = \frac{\sigma_v^2}{1-\rho^2} \qquad cov(\theta, \tilde{\theta}) = p = var(\tilde{\theta}) \qquad cov(k, \tilde{\theta}) = 0 \tag{8}$$

$$(1 - \frac{\rho}{\beta\lambda})cov(\theta, k^i) = \frac{(1-\rho^2)p - \sigma_v^2}{(\rho-\lambda)(1-\rho^2)} \tag{9}$$

$$(1 - \frac{1}{(\beta\lambda)^2})var(k) = \frac{\sigma_v^2 - (1-\rho^2)p}{(\rho-\lambda)^2(1-\rho^2)} \frac{\beta\lambda+\rho}{\beta\lambda-\rho} \tag{10}$$

Note in particular the effects of precision, measured as $\frac{2}{\sigma_\varepsilon^2} + \frac{1}{\sigma_w^2}$ on the variance of k^i. If there is no precision at all in the measurement of θ i.e. the variances of σ_ε^2 and σ_w^2 are infinite, then $p = \sigma_v^2/(1-\rho^2)$, so that the $var(k^i)$=0. The reason for this is that the conditional value of θ_t will now be 0 for all t, and the optimal strategy for firms will therefore be independent of any the stochastic effects. As the precision of w increases i.e. as its variance decreases, the value of p decreases, and $var(k^i)$ increases. The latter reaches its maximum when $\sigma_w^2 = 0$, at which point $p = \sigma_v^2$. Of course, if there is no precision in the public signal, but σ_ε^2 is finite, then the value of p will lie somewhere between σ_v^2 and $\sigma_v^2/(1-\rho^2)$.

3 The effect of public information on welfare

In this section we take a rather narrow view of welfare. However, rather than specify a particular social welfare function, we examine the components that we may regard as making up welfare, and examine the effects that improved public information may have on each. We consider three components: first, the profit of firms, as described in the previous section. Second is consumer surplus; the demand function (2) will lead to a consumer surplus which is the expected value of bY_i^2 for each sector i. Note that a more careful analysis of consumer welfare based on an underlying utility function would lead to a quadratic form in each type of output, but standard convexity assumptions on the utility function, and the equivalence of output in each sector would still lead to consumer welfare that is a positive function of the expected value of Y^2. It follows that consumer welfare can be written as a positive function of $var(k^i)$. Finally, we shall assume that a further welfare component is the loss from price variation i.e. a loss proportional to sum of $var(P^i)$.

In order to calculate the first of these components, it is sufficient to obtain the long run expected value of the period welfare in (1)

$$\begin{aligned} W^{firm} &= E[P_t^i k_t^i - \frac{1}{2}(k_{t+1}^i - k_i^t)^2] \\ &= E[(-bk_t^i + \theta_t + \varepsilon_t^i)k_t^i - \frac{1}{2}(k_{t+1}^i - k_i^t)^2] \\ &= -bvar(k) + cov(\theta, k) - var(k) + cov(k_{t+1}^i, k_t^i) \\ &= -bvar(k) + cov(\theta, k) - var(k) + \frac{1}{\beta\lambda}var(k) - \frac{\rho}{\rho - \lambda}cov(\theta, k) \end{aligned} \tag{11}$$

Noting that from (7) we can write $\frac{1}{\beta\lambda} - 1 - b = -\lambda(1 - \frac{1}{\beta\lambda})$, it follows that after further effort we can write

$$W^{firm} = \frac{\lambda(1-\rho)(\sigma_v^2 - (1-\rho^2)p)}{(\rho-\lambda)^2(1-\rho^2)(1-\frac{\rho}{\beta\lambda})(\beta\lambda+1)} \tag{12}$$

It follows that if this is to made as large as possible, then p must be made as small as possible. Thus the precision, as defined earlier, needs to be as large as possible, so that the noise in the public signal should be equal to zero.

Consider now the welfare of consumers. As discussed above, this is a positive function of the variance of the capital stock, given by (10). If the aim were solely to maximize consumer surplus, then it would be necessary to set the value of p to be as small as possible, thereby maximizing the variance of capital stock. Once again, the optimum policy on the part of the policymaker would be to maximize the value of public information by setting $\sigma_w^2 = 0$.

Finally we consider the loss from price volatility. The variance of prices in the ith industry is given by

$$\begin{aligned} E(P_t^i)^2 &= E(-bk_t^i + \theta_t + \varepsilon_t^i)^2 \\ &= b^2 var(k) + \frac{\sigma_v^2}{1-\rho^2} + \sigma_\varepsilon^2 - 2bcov(\theta, k) \end{aligned} \tag{13}$$

After some considerable effort it can be shown that

$$E(P_t^i)^2 = \frac{\sigma_v^2}{1-\rho^2} + \sigma_\varepsilon^2 - \frac{b\beta\lambda[\lambda(1+\beta)(1-\rho) + (\lambda-\rho)(1+\beta\lambda)]}{(\beta\lambda+1)(\beta\lambda-\rho)(\rho-\lambda)^2(1-\rho^2)}(\sigma_v^2 - (1-\rho^2)p) \tag{14}$$

To minimize this loss, it is clear that p needs to be set as low as possible, which means that the noise in the public signal must be set to zero. We therefore arrive at the following summary of the results of this section:

Proposition 2

(a) The optimum policy is for the monetary authority to reveal information uncontaminated by noise.

(b) The monetary authority should be as revealing as possible about its own information, even if that information is not as full as it may desire.

Proof (a) follows from the results above. (b) is true since it can be shown from (6) that p is always increasing in σ_w^2.

The intuition behind the result of Proposition 2(a) relies completely on Proposition 1. Given that the equilibrium dynamics correspond to all information being pooled, additional public information leads to greater accuracy in estimating the shocks θ_t. This increase in accuracy does not guarantee that the value of the objective function for a forward-looking system will improve - in fact, the results on this are equivocal. However there is a formal equivalence between the model studied here and another, which is a backward-looking one. The model of (1) and (2) assumes that individual firms within each industry take prices as given by (2), but do not choose the price strategically. Straightforward algebra shows that exactly the same solution (4) is obtained if the industry acts strategically to solve a *standard* optimal control problem of the form (1), but with the demand equation given by $P_t^i = -\frac{b}{2}k_t^i + \theta_t + \epsilon_t^i$. But the value function of a standard (linear-quadratic) optimal control problem increases with increased accuracy of the observations, hence the value to firms of increased transparency. The welfare benefit to consumers of increasing the variance of the capital stock by increasing public information is evident from the earlier discussion in this section. As regards price volatility, on the one hand increased information raises the variance of the capital stock; but on the other hand it increases the correlation between the capital stock and the monetary shock because the former can now react more accurately to the latter. Since the latter effect dominates, price volatility declines with increased information.

4 Comparison with other economic transparency results

Not all aspects of economic transparency address identical issues. An example of a different aspect that provides the starkest effect of economic transparency emerges in a one-shot game in the context of a Barro-Gordon model. It applies whether or not the central bank lacks reputation and must act in a time-consistent manner. Then, no matter whether it is able to reveal the full extent of the supply shock or else to provide its own private noisy signal, the optimum policy is to give itself scope to respond to this signal (Cukierman (2001)). Otherwise it is unable to spring any surprise beneficial countercyclical policy. For an alternative model, with an IS curve, and an output gap effect on next period's inflation, social welfare is only reduced by forecasts of shocks if the policymaker cares about interest rate variability. However, these results may be overturned if there is uncertainty about the policymaker's targets (operational transparency); there is an incentive effect of transparency, because it enables private agents to infer the target more easily. The overall result is that the homogeneous agent literature is somewhat equivocal about the benefits of economic transparency.

Directly related to our results are those which stem from the imperfect common knowledge model of Woodford (2001), which is based on the assumption of imperfect competition between firms. A more conventional approach to deriving the same model is provided by Amato *et al.* (2003) who assume that there are supply and demand functions for good i given by

$$Y^{iS} = c(P^i - E_i(P)) \qquad Y^{iD} = E_i(\theta) - P^i \tag{15}$$

where P is the average of all prices P^i over the infinite set of goods, and E_i denotes expectations by the producer of good i based on an information set comprising both public y, and private x_i, observations of θ:

$$y = \theta + w \qquad x_i = \theta + \varepsilon_i \tag{16}$$

These represent the only measurements made by agents, so that analysis of the model is achieved by focusing on the price of each good. Assuming market clearing, one obtains

$$P^i = (1-r)E_i(\theta) + rE_i(P) \qquad r = b/(b+1) \tag{17}$$

Money supply θ is unknown, and must be inferred from the above measurements. It is then relatively easy to derive the equilibrium prices of each firm, even though in principle, it appears (as in the model of Section 2) that an infinite regress of expectations is required. It can be shown that these prices are linearly dependent on the two measurements. They turn out to be more heavily weighted towards the public signal y, and less to the private signal x_i than is each firms' estimate of the money supply. Amato *et al.* (2003) then show that if welfare is defined by the variance of prices, increased precision of the private signal always increases welfare. However, for given variance of the private signal, there is a range of level of precision of the public signal over which an increase in that precision level is welfare-reducing. This is due the higher weight of the public signal in prices, compared to its weight on the estimate of the fundamental θ, so that there is a relative over-reaction. Thus if the central bank is limited by its own measurements, there is a range of values of precision for which it is optimum for the announcements of the central bank to be more imprecise than its own information. Similar results are obtained if one makes the assumption of Hellwig (2002) that the money supply is a draw of a normal random variable.

Hellwig (2002) also uses this rudimentary form of the model of Woodford (2001) to address the role of transparency and public information in an optimizing model. He assumes that monetary policy is partly set by the policymaker, and is partly subject to shocks, and is then observed along the lines outlined above. His results are not dissimilar from those of Section 3, in that he finds no role for noisy public information, and that it should be fully revealing.

5 Concluding remarks

The purpose of this paper has been to add some more perspective to the role of economic transparency. Using some recent results on optimizing models with heterogeneous agents with diverse information, we have demonstrated the role that public information may take for the purpose of increasing social welfare. All the welfare effects, whether associated with firms, consumers or price stability, lead to the conclusion that public information should be fully revealing with regard to aggregate demand (money supply) shocks.

We have contrasted this with the conventional homogeneous agent literature, which delivers a mixed message on economic transparency, and the heterogeneous agent literature, which comes down more firmly on some optimal level of precision of public information; this optimal level may not coincide with the central bank's private level of precision. The problem with the latter literature, based on Woodford (2001), is that the informational assumptions are not particularly realistic, especially compared with the model of this paper.

A possible extension of the current model would be along the lines of Woodford (2001), involving a large number of firms and a very general stochastic process for money supply. Then each firm observes the average price and receives (presumably noisy) signals on current average output. This, and the incorporation of optimal monetary policy into the setup, are currently under investigation.

A Outline Proof of Proposition 1

It is straightforward to show that the the optimal choice of capital is given by

$$K^i_{t+1} = K^i_t + E_t \sum_{t=1}^{\infty} \beta^j P^i_{t+j} \tag{A.1}$$

where E_t denotes expectations based on information at time t.

One can then rewrite the system in a standard form for forward-looking rational expectations models as:

$$\begin{aligned} k^i_{t+1} &= (1+b)k^i_t - \epsilon^i_t - \theta_t + g^i_t && \text{(A.2)} \\ \theta_{t+1} &= \rho\theta_t + v_{t+1} && \text{(A.3)} \\ E_t g^i_{t+1} &= \beta^{-1}(g^i_t - P^i_t) && \text{(A.4)} \\ P^i_t &= -bk^i_t + \epsilon^i_t + \theta_t && \text{(A.5)} \end{aligned}$$

together with an additional publicly observed variable

$$m_t = \theta_t + w_t \tag{A.6}$$

To verify that Proposition 1 is correct, assume that it is true for industry 1. Then the system for industry 2 is characterized by the dynamic equations (4), (5), (A.2), (A.3) and (A.4), together with observations of K^1_t, P^1_t, P^2_t, m_t.

Applying the methods of Pearlman *et al.* (1986) and Pearlman and Sargent (2003) then gives the representation of (4) for industry 2 as well.

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